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November 01, 2004

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APPLICATION NUMBER: *60/536,525*
FILING DATE: *January 15, 2004*

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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a **PROVISIONAL APPLICATION FOR PATENT** under 37 CFR 1.53 (b)(2).

Docket Number	27377	Type a plus sign (+) inside this box ->	+

INVENTOR(s) / APPLICANT(s)

LAST NAME	FIRST NAME	MIDDLE INITIAL	RESIDENCE (CITY AND EITHER STATE OR FOREIGN COUNTRY)
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TITLE OF THE INVENTION (280 characters max)

NANO-TECHNOLOGY BASED 3D VIDEO SAMPLER

CORRESPONDENCE ADDRESS

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ENCLOSED APPLICATION PARTS *(check all that apply)*

☑ **Specification**	*Number of Pages*	5	☑ **Applicant is entitled to Small Entity Status**
☑ **Drawing(s)**	*Number of Sheets*	5	☑ **Other** (specify) **3 Claims**

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT *(check one)*

☐ A check or money order is enclosed to cover the filing fees ☑ The Commissioner is hereby authorized to charge filing fees and credit Deposit Account Number: **50-1407**	**FILING FEE AMOUNT ($)**	**$ 80.-**

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

☑ No

☐ Yes, the name of the US Government agency and the Government contract number are: ______________

Respectfully submitted,

SIGNATURE Sol Sheinbein

13 January 2004
Date

25,457
REGISTRATION NO.
(if appropriate)

TYPED or PRINTED NAME SOL SHEINBEIN

☐ Additional inventors are being named on separately numbered sheets attached hereto

USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

Burden House Statement: This form is estimated to take 2 hours to complete. Time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form should be sent to the Chief Information Officer, Patent and Trademark Office, Washington DC 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Box Provisional Application, Assistant Commissioner for Patents, Washington, DC 20231.

Nano-Technology based 3D Video Sampler

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December 1, 2003

1 3D Scanners

There are many ways to scan the 3D shape of objects, like shape from shading, shape from stereo, shape from photometric stereo, shape from structured light, shape from coded light, etc. For example, some laser scanners that can be found in some commercial products can be classified as part of the structured light technique.

In order to obtain real time 3D sensing, several new techniques have bee recently developed: The 3D structure of an object can be computed from the optical recorded deformation of a single known pattern. However, texture of the object may cause matching problems and significant inaccuracies. Another interesting idea is that of 3DV-systems that is based on measuring the travel time of a pulse of light. Nevertheless, such implementations require controlled environments sensitive to textures, and extremely expensive.

Here we propose a different simple solution for the 3D video scanning problem. It is based on a recent nano-technology development that allows the classical coded light technique to work in real time with minor modification of existing CMOS sensing technology. The idea is to efficiently project a sequence of binary patterns, and according to the binary time sequence, sensed at each pixel of an imaging sensor, the disparity is computed to yield the 3D shape of the object. This technique known as coded light is not new. The innovation is the method to do it in real time.

2 The patent

In this patent we propose to couple a new technology known as Digital Micromirror Device (DMD), that is found at the heart of Digital Light Processing (DLP) systems, with existing CMOS optical sensor technologies (digital CMOS cameras) in order to build a time modulation, coded light, 3D video sensor. A prototype working at 0.7 frames per second was built as a proof of concept at the GIP lab at the Technion.

The following is a summary of the relevant information taken from *www.dlp.com*

Digital Light Processing is currently used mainly for digital projectors. These DLP projectors are based on an optical semiconductor known as the Digital Micromirror Device, or DMD chip, which was invented by Dr. Larry Hornbeck of Texas Instruments in 1987. The DMD chip is probably the world's most sophisticated light switch. It contains a rectangular array of up to 1.3 million hinge-mounted microscopic mirrors; each of these micromirrors measures less than one-fifth the width of a human hair, and corresponds to one pixel in a projected image. When a DMD chip is coordinated with a digital video or graphic signal, a light source, and a projection lens, its mirrors can reflect an all-digital image onto a screen or other surface. The DMD and the sophisticated electronics that surround it are what we call Digital Light Processing technology.

A DMD panel's micromirrors are mounted on tiny hinges that enable them to tilt either toward the light source in a DLP projection system (ON) or away from it (OFF)- creating a light or dark pixel on the projection surface.

The bit-streamed image code entering the semiconductor directs each mirror to switch on and off up to several thousand times per second. When a mirror is switched on more frequently than off, it reflects a light gray pixel; a mirror that's switched off more frequently reflects a darker gray pixel.

This way, the mirrors in a DLP projection system can reflect pixels in up to 1,024 shades of gray to convert the video or graphic signal entering the DMD into a highly detailed gray-scale image.

At the other end, existing CMOS technology enables us to easily sense 1000 frames per second. Communicating the captured images to a processing unit is a challenging task, yet, we need to remember that only binary information per each projected textured frame needs to be transmitted. Think of a sequence for which the first pattern is "white" the second "black". These define the lower and upper values of our local dynamic range. The next, say 8, binary patterns need to be thresholded at the local mid-range. And the process repeats itself every 10 patterns. This way a sequence of 1000 projected patterns per second could provide more than 100× 8bits layer per second, where each such 8bits frame represents a depth profile. This is nothing but depth map transmitted at real time.

That is, we couple the DMD capability for time modulation of binary patterns, with a simple CMOS sensor with local synchronization to allow real time 3D scanner. A prototype actually exists in our lab, as our coded light 3D scanner, and works at 0.7pps. The above coupling would allow an improvement of two orders of magnitude in time.

Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. The materials, methods, and examples provided herein are illustrative only and not intended to be limiting.

Implementation of the method and system of the present invention involves performing or completing certain selected tasks or steps such as scanning manually, automatically, or a combination thereof. Moreover, according to actual instrumentation and equipment of preferred embodiments of the method and system of the present invention, several selected steps could be implemented by hardware or by software on any operating system of any firmware or a combination thereof. For example, as hardware, selected steps of the invention could be implemented as a chip or a circuit. As software, selected steps of the invention could be implemented as a plurality of software instructions being executed by a computer using any suitable operating system. In any case, selected steps of the method and system of the invention could be described as being performed by a data processor, such as a computing platform for executing a plurality of instructions.

The invention is herein described, by way of example only, with reference to the accompanying drawings. With specific reference now to the drawings in detail, it is stressed that the particulars shown are by way of example and for purposes of illustrative discussion of the preferred embodiments of the present invention only, and are presented in the cause of providing what is believed to be the most useful and readily understood description of the principles and conceptual aspects of the invention. In this regard, no attempt is made to show structural details of the invention in more detail than is necessary for a fundamental understanding of the invention, the description taken with the drawings making apparent to those skilled in the art how the several forms of the invention may be embodied in practice.

The drawings taken in order show

1) an existing system for data acquisition which suffers from a long acquisition time

2) a first system using DLP and a high frame rate CMOS camera. In this first system there are difficulties in synchronizing between the camera and the DLP and in which the

sensor and the DLP are not synchronized, and the system can require a very high data bit rate

3) a second system being a preferred embodiment of the present invention, in which the DLP is synchronized with a special purpose CMOS camera. The resulting scan data is preprocessed and the system leads to real time 3D data scanning.

4) a flow chart illustrating operation of the second system, and

5) an operation diagram illustrating the signals at the various flow chart stages.

It is expected that during the life of this patent many relevant imaging devices and systems will be developed and the scope of the terms herein, particularly of the terms "camera" and "imaging system", is intended to include all such new technologies *a priori*.

It is appreciated that certain features of the invention, which are, for clarity, described in the context of separate embodiments, may also be provided in combination in a single embodiment. Conversely, various features of the invention, which are, for brevity, described in the context of a single embodiment, may also be provided separately or in any suitable subcombination.

Although the invention has been described in conjunction with specific embodiments thereof, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art. Accordingly, it is intended to embrace all such alternatives, modifications and variations that fall within the spirit and broad scope of the appended claims. All publications, patents and patent applications mentioned in this specification are herein incorporated in their entirety by reference into the specification, to the same extent as if each individual publication, patent or patent application was specifically and individually indicated to be incorporated herein by reference. In addition, citation or identification of any reference in this application shall not be construed as an admission that such reference is available as prior art to the present invention.

Claims

1. A 3D scanning device substantially as hereinbefore described with reference to the accompanying drawings.

2. A 3D scanning method substantially as hereinbefore described with reference to the accompanying drawings.

3. A 3D scanning device comprising:

a digital light processing unit bearing a digital micromirror device for encoding a rapidly changing time signal onto a light beam directed to an object,

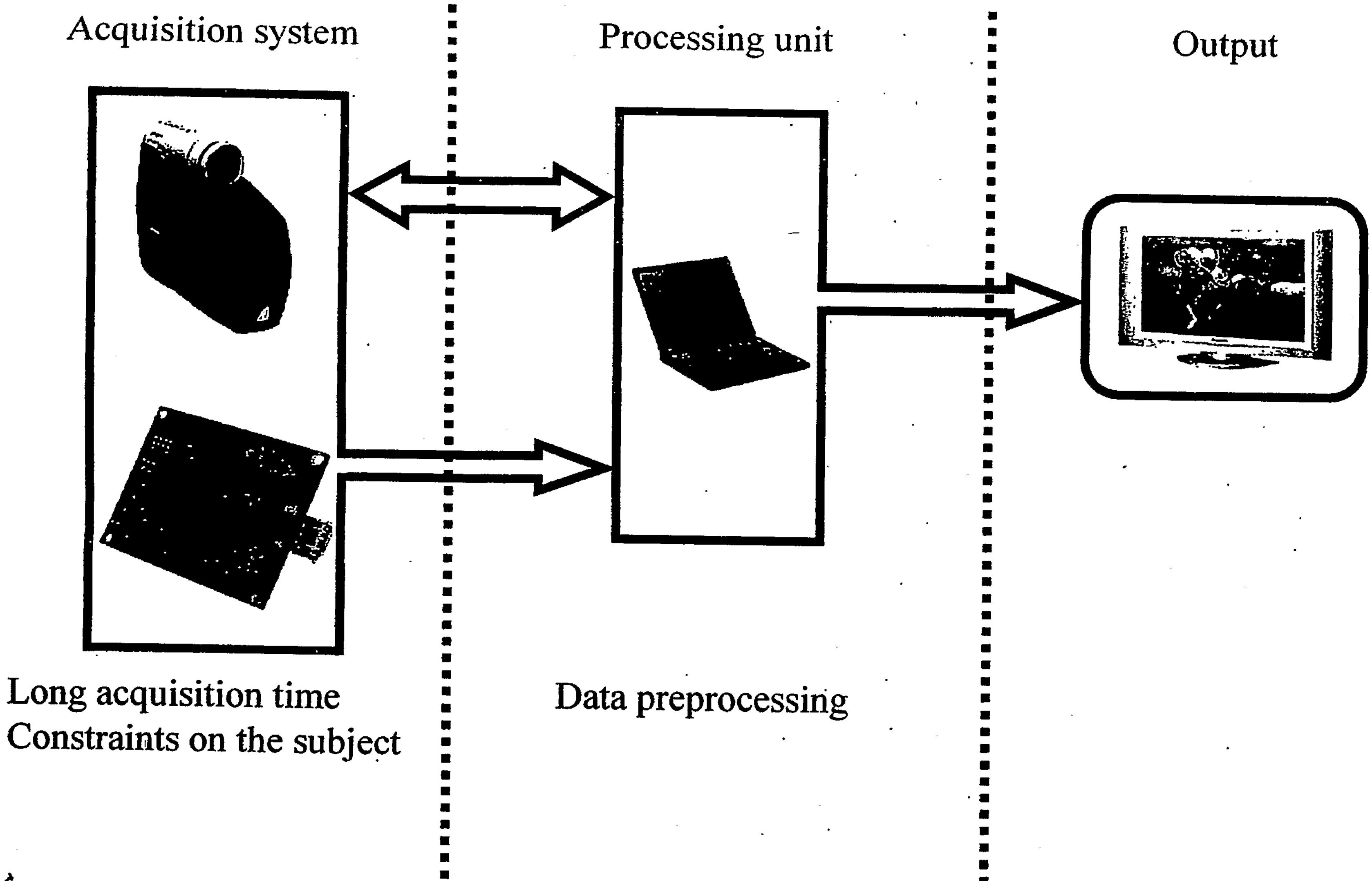
a detector synchronized with said digital light processing unit for detecting reflections of said light beam from said object,

a preprocessor for thresholding and encoding pixels of said detected reflections, and

a decoder for determining a 3D shape of said object from distortions of said time signal in said detected reflections.

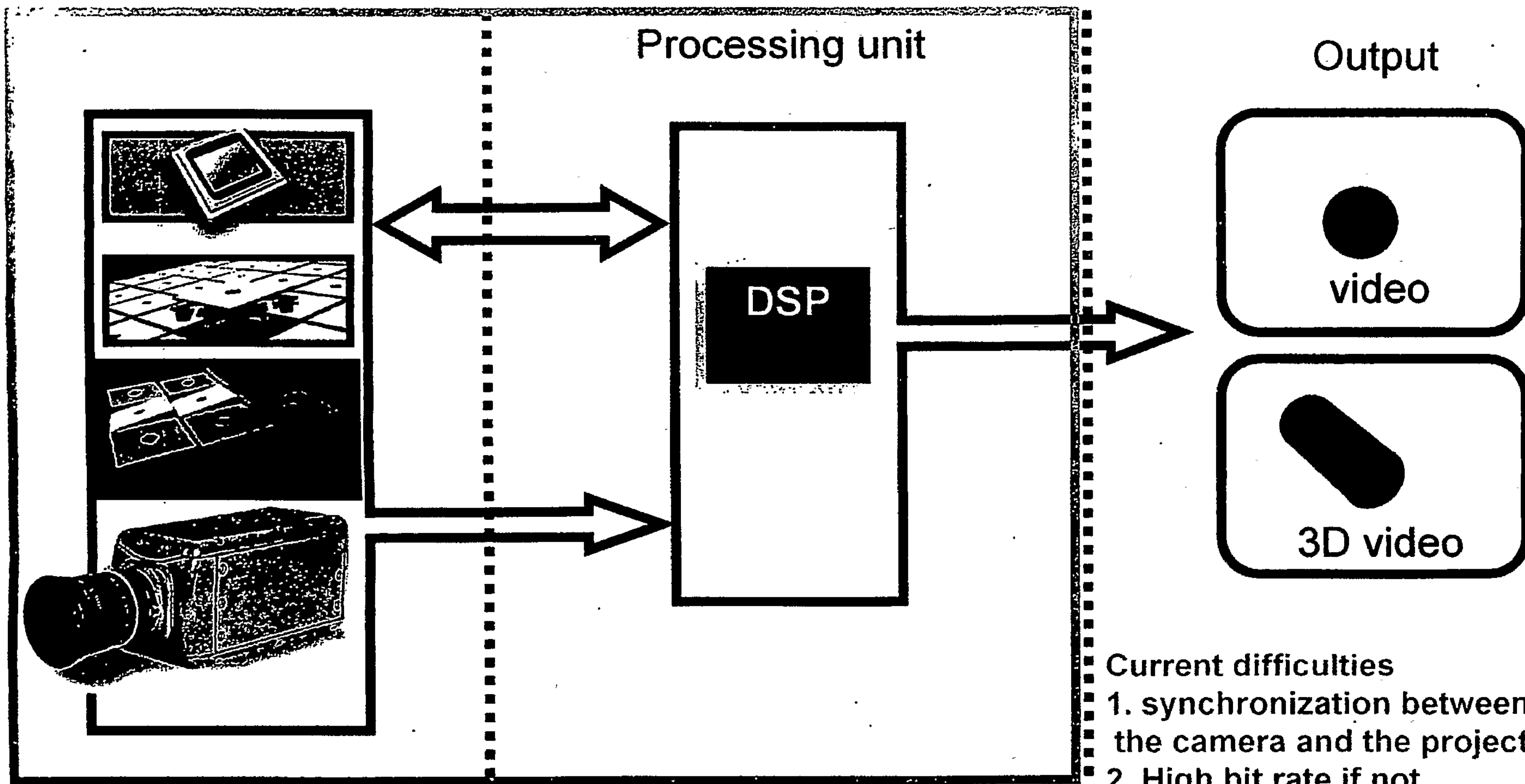
Prior Art

DLP projector + Firewire (IEEE 1394) PT gray camera



3D video digitizer Version

DLP projector + High frame rate CMOS camera



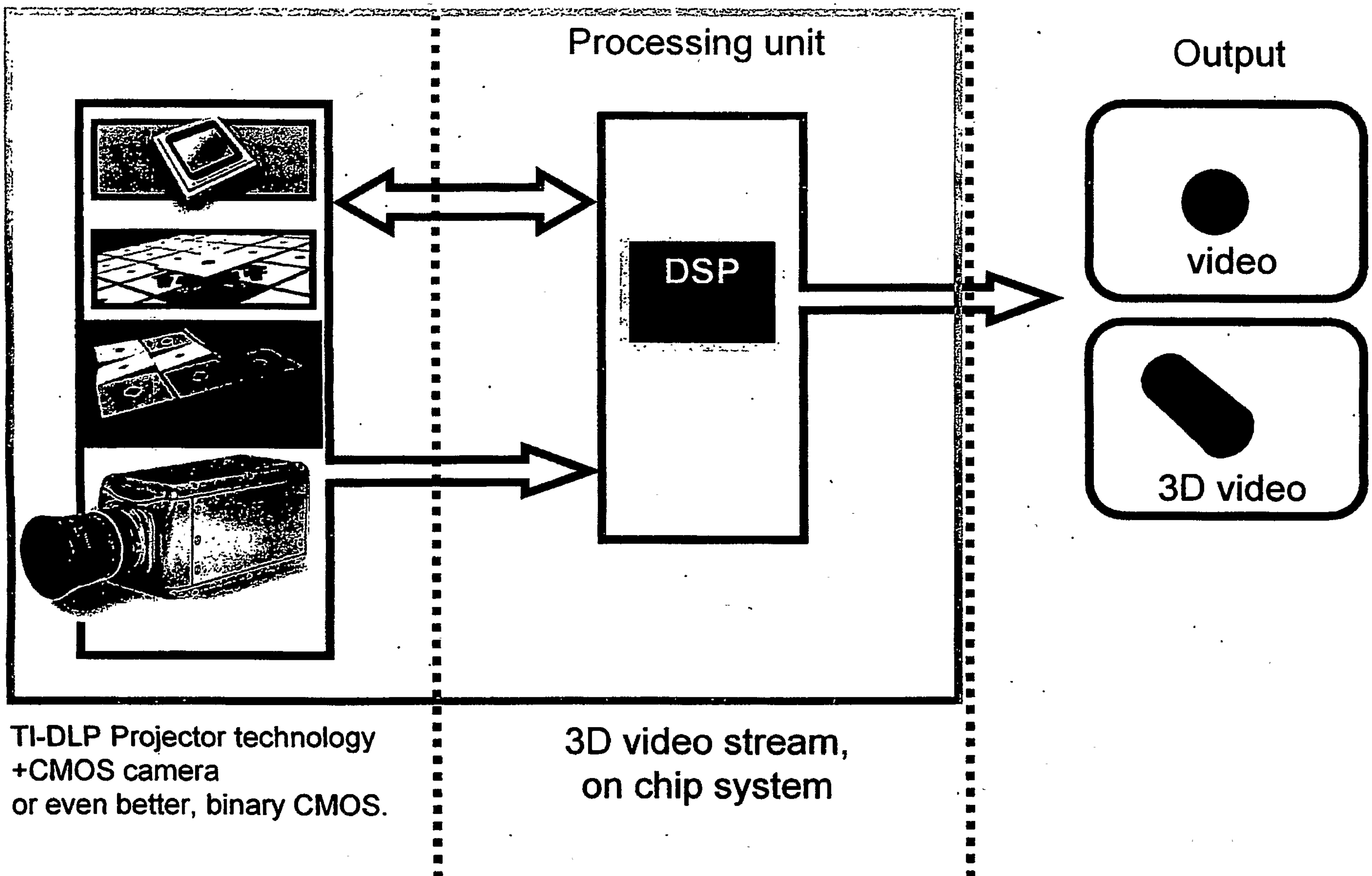
TI-DLP Projector technology
+high frame rate CMOS
camera.

3D video stream

Current difficulties
1. synchronization between the camera and the projector
2. High bit rate if not pre-processed.

3D video digitizer Version

Synchronized DLP projector + Special purpose CMOS camera



TI-DLP Projector technology
+CMOS camera
or even better, binary CMOS.

3D video stream,
on chip system

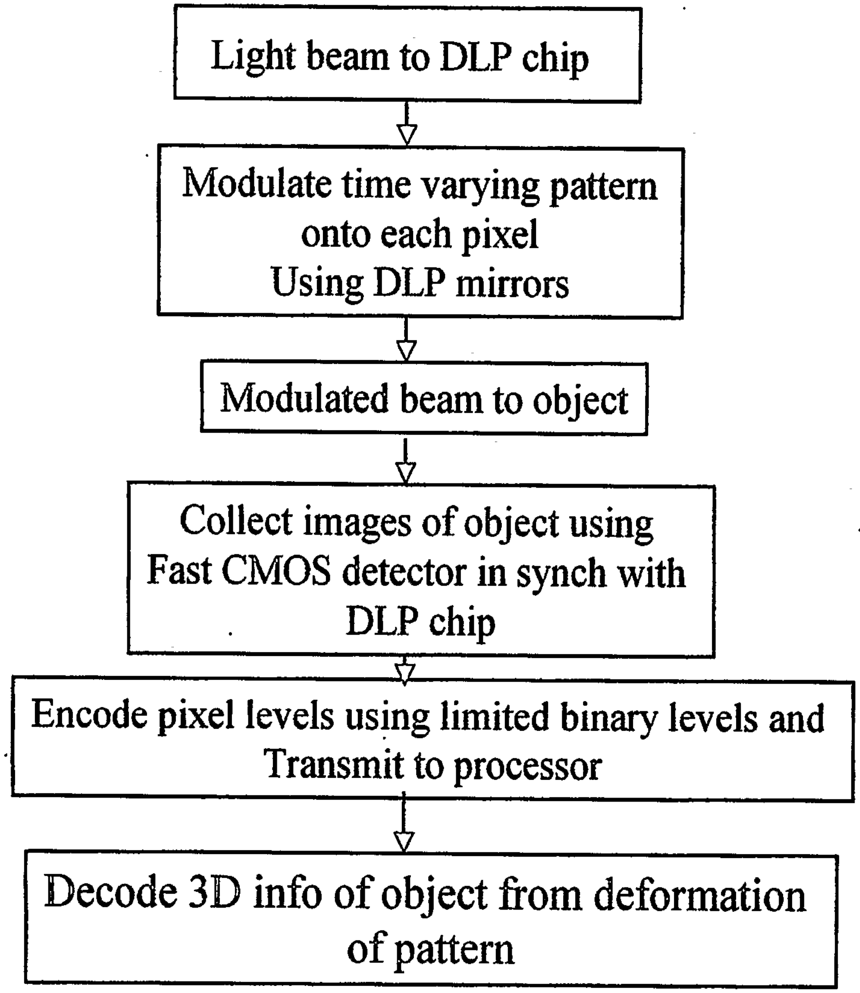
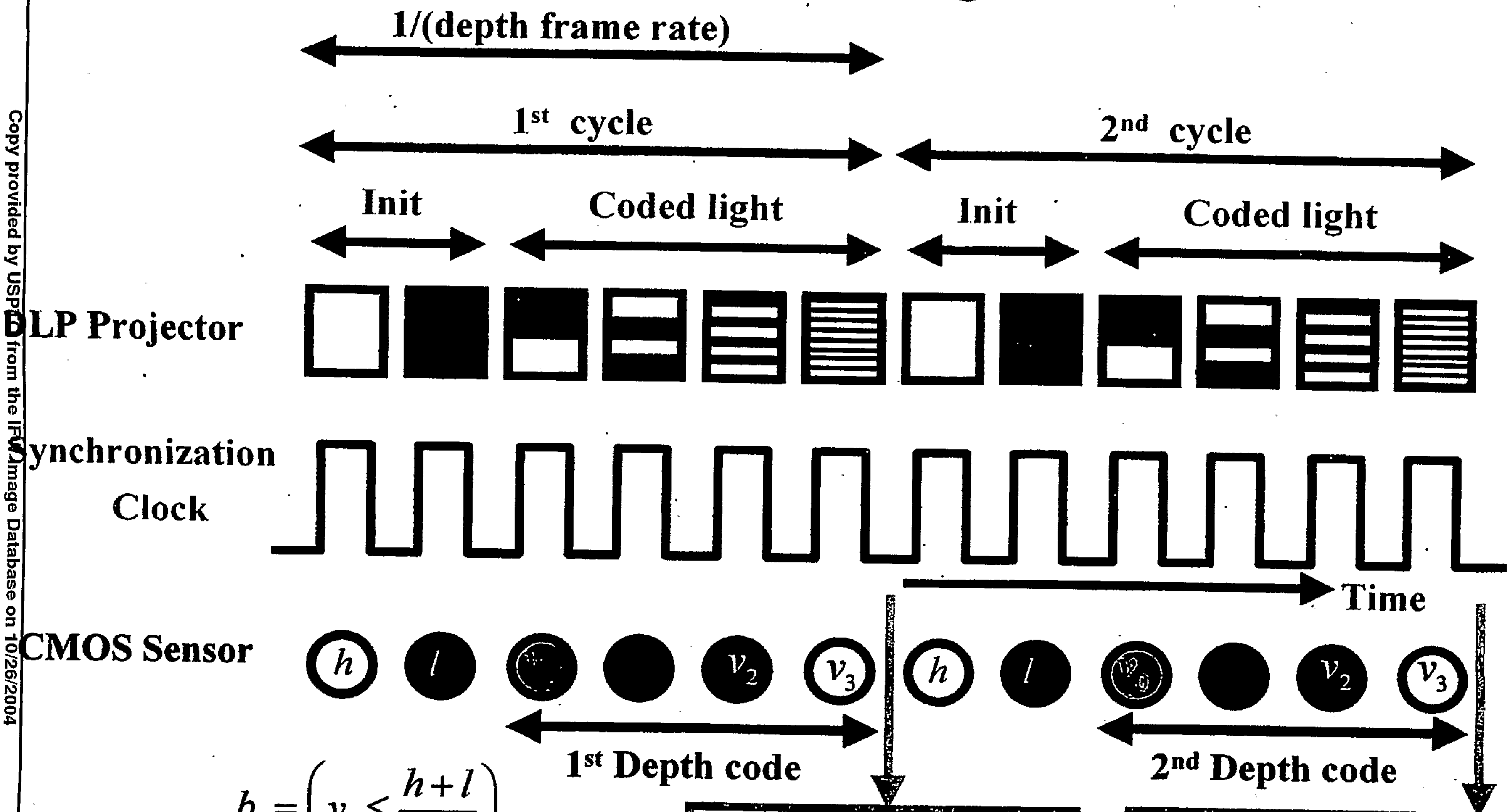

Light beam to DLP chip
Modulate time varying pattern onto each pixel Using DLP mirrors
Modulated beam to object
Collect images of object using Fast CMOS detector in synch with DLP chip
Encode pixel levels using limited binary levels and Transmit to processor
Decode 3D info of object from deformation of pattern

Fig 4

Operation Diagram



$$b_i = \left(v_i \le \frac{h+l}{2} \right)$$

Bits rate ~ Frame Size (pixels) * Clock Rate